LETTER REPORT
SITE-SPECIFIC TIME RESPONSE SPECTRA
EXISTING UTAH STATE CAPITOL BUILDING
350 NORTH COLUMBUS STREET (100 EAST)
SALT LAKE CITY, UTAH

Submitted To:

Capitol Preservation Board
% Cooper/Roberts Architects
700 North 200 West
Salt Lake City, Utah 84114

Submitted By:

AGRA Earth & Environmental, Inc.
Salt Lake City, Utah

July 28, 2000

Job No. 0-817-002957

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July 28, 2000
Job No. 0-817-002957

Mr. Wallace Cooper
Capitol Preservation Board
% Cooper/Roberts Architects
700 North 200 West
Salt Lake City, Utah 84114

Re: Letter Report
Site-Specific Time Response Spectra
Existing Utah State Capitol Building
350 North Columbus Street (100 East)
Salt Lake City, Utah

Dear Mr. Cooper:

1 INTRODUCTION

1.1 GENERAL

This letter presents our site-specific seismic response study for the State Capitol Building located at 350 North Columbus Street (100 East) Street in Salt Lake City, Utah. SHB AGRA previously completed a geoseismic study for this site in 1992[1] and a supplemental geoseismic and geotechnical evaluation in 1996[2]. This letter report supplements these previous studies and provides recommended response spectra based on the most recent United States Geologic Survey (USGS) ground motion data and site-specific shear wave velocity testing.

1.2 OBJECTIVES AND SCOPE

We understand that it is proposed to support the existing structure on a base isolation system for seismic rehabilitation purposes. Based on the base isolation concept, the objectives and scope of our current study were planned in discussions between Mr. Parry Brown of Reaveley Structural Engineers and Mr. William Gordon of AGRA Earth & Environmental, Inc. (AGRA). Specific items

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Report: Geoseismic and Geotechnical Consultation, Seismic Retrofit Study, Utah State Capitol Building, DFCM Project No. FS:92-120, SHB AGRA Job No. E92-2365, November 23, 1992.

2 Report: Geoseismic and Geotechnical Evaluation, Existing Utah State Capitol Building Remodel/Seismic Study, DFCM Project No. FX95045-S, AGRA Job No. 6-817-2052, June 13, 1996.

required during the course of the study were also discussed in telephone conversations between Reaveley Engineers, Forell Associates, and AGRA.

In general, the objective of this study was to evaluate the site-specific seismic response for design of the proposed rehabilitation of the State Capitol building. In accomplishing this objective, our scope included the following:

1. Review of available geotechnical information pertinent to this site
2. A field investigation program consisting of the drilling and logging of one exploratory boring down to a depth of 93.0 feet.
3. Completion of down hole seismic shear wave velocity measurements within the subject boring.
4. Review of published seismicity data pertinent to the site.
5. Selection of available recorded time history data.
6. Completion of one-dimensional SHAKE analyses and development of response spectra at the ground surface.
7. An office program consisting of summarizing the information and developing recommended ground motion response parameters.

During the course of the design work, we understood that the designer of the base isolation system required input time histories in two orthogonal directions for the evaluation of the seismic response of the Capitol structure. These time histories were developed from the output files of our SHAKE analysis. The recommended response spectra were also developed from the square root of the sum of squares (SRSS spectra: ie the peak motion based on orthogonal x and y accelograms).

AUTHORIZATION

Authorization to proceed with the proposed scope of services was provided by Mr. Wally Cooper of Cooper/Roberts Architects.

PROFESSIONAL STATEMENTS

Supporting data upon which our recommendations are based are presented in subsequent sections of this report. Recommendations presented herein are governed by the physical properties of the soils encountered in the exploration borings, projected groundwater conditions, the layout and design data previously discussed in AGRA's reports referenced in the following section, and the available mapped fault hazards in the Salt Lake City area. If subsurface conditions other than

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those described in this report, or previous AGRA reports, are encountered and/or if design and layout changes are implemented, AGRA must be informed so that our recommendations can be reviewed and amended, if necessary.

Our professional services have been performed, our findings obtained, and our recommendations prepared in accordance with generally accepted engineering principles and practices followed at this time.

2. PROPOSED CONSTRUCTION

The existing Capitol building is a relatively heavy structure supported by a system of interior and exterior isolated spread footings. The "Capitol Dome" is supported by a system of two columns supported by spread footings and shear walls. Two columns form the corners of a triangle and are about 35 feet apart in plan. Extending from the two columns are two shear walls which meet at a point, forming a triangle. These shear walls are 30 feet in length. A 35 feet long shear wall is also located between the two columns, forming a triangle to resist lateral forces. Existing dead loads for the Capitol building are approximately as follows:

Location	Dimension, ft	Maximum Load, Kips	Bearing Pressure, KSF
Exterior Column Footings	7 by 7	550	11.2
Interior Columns	7 by 7	460	9.4
	4 by 4	20	1.25
Dome Foundation	Triangle, 30 by 30 by 35	8600	20.1

The above loads vary slightly from those previously provided in our referenced 1992 report.

We understand that it is proposed to install a base isolation system below the Utah State Capitol Building. The proposed system will involve relatively complicated construction involving placement of a large mat foundation below the entire building. In addition, a minimum of eight and one-half feet of basement head room is desired. The mat will be installed by excavating around existing footings and transferring the column loads onto the mat. Individual column loads will need to be temporarily supported, the foundation removed, and the loads transferred onto the mat. Excavations up to seven feet below the existing floor grade may be required to accomplish the installation of the mat and transfer of the loads to the mat.

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3. INVESTIGATIONS

Our referenced 1996 investigation of the surrounding State Capitol provides a summary of surface site conditions, field and laboratory investigations, and site seismicity at the State Capitol. This report should be referenced for details.

3.1 FIELD PROGRAM

A field program was completed to obtain a site-specific compression and shear wave velocities at the State Capitol site. One exploration boring was advanced to a depth of 93.0 feet, at which depth practical refusal was encountered. The boring was advanced using an air operated rotary percussion drill rig. The percussion drilling method is capable of drilling to greater depths than was possible using the hollow-stem auger drill rig used for our previous investigations. The location of the boring was in the lawn area to the west of the Capitol building as shown on Figure 1, Site Plan. Drill hole cuttings were sampled from the return flow from the drill rig. To expedite the drilling process, drive samples were not obtained. The log of the boring is included as Appendix A.

Following completion of the boring, a four-inch diameter PVC casing was grouted into the hole using a bentonite/grout mix to allow completion of down hole seismic compressional and shear wave velocity measurements. The seismic work was completed by LGS Geophysics, Inc. of Salt Lake City, Utah. Results of the shear wave velocity measurements are summarized in Appendix B.

4. GEOTECHNICAL PROFILE

A geotechnical profile was developed based on review of our earlier drill holes, the supplemental drill hole logged as part of this investigation, and the shear wave velocity measurements summarized in Appendix B. The soils to a depth of 35.0 feet consist of stratified sequences of fine sandy silts, clean to silty fine sands, and layers of silty to sandy gravel with a few cobbles. The soil stratification is indicative of lacustrine (lake bed) beach type deposits associated with prehistoric Lake Bonneville deposition. Shear wave velocities within these soils was generally less than 1000 feet per second, which is low considering the sands and gravels present and the dry nature of these soils.

Soils below a depth of 35 feet to the maximum depth investigated were a sequence of silts, sands, and gravels with perhaps one or more silty clay layers present. These soils contain occasional to numerous sandy silt and fine to very fine sand seams. The deposits likely represent deeper water Lake Bonneville deposits. Shear wave velocity of these deposits was generally between 1100 and 1200 feet per second. Our 1996 study estimated that the shear wave velocities would range greater than 1300 feet per second. The relatively low measured shear wave velocities could be attributed to numerous sand and silt layers within the soil profile. These lower shear wave velocities impact the site response, particularly at periods greater than 0.5 seconds.

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No groundwater was encountered within our previous investigations or within this investigation to a depth of 93 feet.

The soil profile used in our analysis is shown on Figure 2, Soil Profile for Seismic Analysis. This profile was based on the earlier Boring B-1 and supplemental Boring B-2A. Further detail regarding subsurface soil conditions is contained in our 1996 report.

5. SITE-SPECIFIC GROUND RESPONSE

As discussed in our previous referenced reports, the State Capitol is located in close proximity to the Warm Springs Segment of the Wasatch fault. Based on the site location and published response spectra (Adan and Rollins, 1992; Wong and Silva, 1993), it was anticipated that potential ground motions for design of the retrofit of the State Capitol could exceed the Uniform Building Code Response Spectra. Specifically, it was anticipated that the UBC spectra would be exceeded at relatively short periods of less than 0.5 seconds for both the design basis earthquake (BSE-1 event, 10 percent in 50 year event) and maximum credible earthquake (BSE-2, or MCE event).

Subsequent to our 1996 report, the USGS (United State Geologic Survey) published probablistic ground motions for the western United States. These data are available at the USGS web site. As a check on the previous 1996 report, the peak horizontal and spectral accelerations on the Soil Type B-C boundary (soft rock to dense soil boundary) were obtained. These data are as follows:

Table 1 - Summary of USGS Soil Type B-C Boundary Peak Accelerations and Spectra

	10 percent PE in 50 yr	5 percent PE in 50 yr	2 percent PE in 50 yr
Peak Ground Acceleration, g	28.94103	52.59599	87.49070
0.2 Second Spectral Acceleration	64.65861	117.7811	182.5703
0.3 Second Spectral Acceleration	60.87698	113.4463	177.7571
1.0 Second Spectral Acceleration	22.00630	43.82281	76.85534

Note all values in percent gravity (divide by 100 to obtain "g")

Our 1996 report utilized earlier work by Adan and Rollins to define the peak horizontal ground motions for the site. These recommended 1996 peak horizontal acceleration values on the Soil Type B-C boundary were modified to the USGS peak accelerations, as follows on the next page.

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The BSE-1 earthquake (10 percent in 50 year event) was taken directly from the USGS published values.

The MCE event was determined by averaging attenuation relationships published by Joyner and Boore (1988), and Campbell (1994, 1997).

Consideration was also given to the peak ground accelerations provided in Adan and Rollings, and Wong and Silva.

The following peak accelerations were developed for "scaling" input ground motions:

Table 2 - Summary of Peak Input Accelerations on Soil B-C

Event	Previously Recommended Value (1996 Report)	Current Recommended Value
BSE-1 - 10 percent in 50 year event	0.35 g	0.29 g
BSE -2 (MCE Event)	0.70 g	0.77 g

The average recurrence interval of an MCE event is estimated to be on the order of 1300 years. For comparison, the recurrence interval of the 2 percent in 50 year event is by definition 2375 years.

5.1 APPROACH

Site-specific response analyses were completed by developing a "one-dimensional" soil column below the Capitol building based on soil properties and shear wave velocities. The above "bedrock" time histories were input at the base of the column and propagated through the column to obtain the site-specific time history at the surface and resulting response spectra. More specifically, the approach used to calculate the site response was as follows:

Appropriate bedrock time history data were selected from a database of available time history data (accelerograms). Initial response spectra were developed for only the peak component of ground motion. Following submission of the original time response spectra, it was requested by the designers that orthogonal pairs of output time histories (soil time histories) be developed at the ground surface. This critical step in our analysis is complicated by the fact that there are essentially no "good" strong ground motion data from normal faulting events in the intermountain region, which meet all the criteria of peak acceleration, site to source distance, and earthquake duration. It is therefore customary in the Salt Lake Valley to use recorded events from California or other "normal faulting" regions in the world. Our approach was to select seven time histories which cover the broad band of possible input rock ground motions. From these time histories, representative low, medium, and peak response values were selected for analysis. The response spectra recommended for the site was therefore based on enveloping the possible range in ground motions.

The site-specific soil properties were determined based on the field shear wave velocity measurements. The pertinent soil properties included distribution of soil types, total unit weight (TD), at rest pressure coefficient (Ko), depth to water, and Shear Wave Velocity, Vs. Estimates of damping and soil modulus were derived from published relationships between damping versus shear strain, and shear modulus versus shear strain.

The peak acceleration component of the selected time histories on rock (Soil B-C) were scaled to the stiff soil/rock[3] peak horizontal accelerations representing the 10 percent in 50 year and MCE event.

The scaled time histories were input as a "bedrock" ground motion at a depth of 100 feet below grade. Note that drill rig refusal was encountered at a depth of 93.0 feet. The 100 feet depth is customary in an analysis of this type.

One-dimensional SHAKE analyses were completed through the soil column using up to seven recorded time histories. Scaling of several time histories affected convergence of the SHAKE analysis. These results are not presented on the attached figures.

As requested by the designers, the response spectra at 5 percent, 10 percent, 15 percent, 20 percent, 30 percent, and 40 percent damping were calculated. These spectra were compared to the UBC 1997 smoothed spectra for Soil Site Class D. Similar smooth spectra may also be calculated for the IBC 2000 code using the 2 percent in 50 year values provided in Table 1.

5.2 TECHNICAL DISCUSSION

A number of time histories were selected as "input ground motions." The considerations in selection of the time histories included: a) a peak acceleration in the range of 0.10 to 0.30 g, which are representative for a 10 percent in 50 year event, b) ground motions should have been obtained on either stiff soil or bedrock, and c) the 0.05 g bracketed duration of the ground motion should be in the 10 to 15 second range. Normal fault records meeting these characteristics were not found. After review of a number of time histories, the time histories described on the next page in Table 3, Input Ground Motion Data, were selected.

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[3] Defined as the soil type B-C boundry.

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Table 3 - Input Ground Motion Data

Time History	Peak Acceleration (before scaling)	Description
Loma Prieta-(hollister)	0.282 g	A record of the 1989 Loma Prieta, California strike-slip movements recorded at the Hollister Airport (M_M 7.0, Distance 45 kilometers).
Helena	0.15 g	A digitized record of the M 6.0 event near Helena, Montana. The duration and energy content of this event was found to be quite low. The event was selected for our analysis because it represents a normal faulting event.
Imperial Valley	0.35 g	This event provided the largest spectrum of site response and is considered to conservatively represent possible ground motions.
Folsom	0.35 g	These records provide an intermediate range of site response. These events have previously been used to evaluate site response of a California Dam.
Weber Earthquake	0.23 g	A synthetic time history developed by the University of Nevada at Reno to represent a near field event on the Weber Segment of the Wasatch fault. Evaluation of the site response indicated that this record tended to attenuate throughout the soil column, versus the amplification observed in the natural time histories. For conservatism, this event was not used in our analysis.
El Centro	0.113	The Superstition Mountain Earthquake, M 5.6 at distance of 22 kilometers. Recorded at Gilroy #1.
Coyote Lake	0.113	A record of the earthquake occurring at Coyote Lake in and recorded at the Gilroy No. 1 site. M 5.8 at a distance of 16 kilometers
Ririe Dam	1.17 g	A Magnitude 7.5 earthquake recorded at Ririe Dam at a distance of 5 kilometers

Soil data used to define the subsurface conditions are shown on Figure 2. This profile is based principally on the 93 feet deep boring drilled at the site specifically for this site response study. Table 4, Soil Properties for Shake Analysis, summarizes the general soil conditions and published

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relationships used to characterize the site. The soil profile was divided into 21 layers each five feet in thickness.

Table 4 - Soil Properties for Shake Analysis

Depths From / To (feet)	General Soil Type	Damping and Modulus Reduction Relationships
0 to 10	Sandy Silt	Sand, Average based on Seed & Idriss 1970
10 to 20	Sandy Gravels	Gravel, Average (Seed et al. 1986)
20 to 35	Sands and Silts	Sand, Average (Seed & Idriss 1970), Seed (1988) [damping]
75 to 95	Dense Sands and Gravels, with silty and sandy layers	Gravel (Mean) - Rollins et al. JGE, V. 124, No. 5, 1998
95 to 100	Dense Cobbles	Gravel (Mean +1) - Rollins et al. JGE, V. 124, No. 5, 1998

The one-dimensional response calculations were completed using the program SHAKE91. This is an updated version of the original 1972 program developed by the University of California, Berkley. Input and output of the data was facilitated by the use of the pre/post processor program, SHAKEdit. Amplification of the peak ground motion was observed in each time history throughout the soil column.

A summary of the initial response spectra developed for this project after scaling the input motions to 0.29 and 0.77 g, is shown on Figure 3, Initial Response Analysis Spectra.

6. FINDINGS

Our analysis for the 10 percent in 50 year and MCE events are summarized on Figures 4 and 5 (Response Spectra Summary for 10 Percent in 50 Year Event and Response Spectra Summary for MCE Event), respectively. The site-specific response for each of the orthogonal ground motions from the Imperial Valley, Helena, and Folsom events is shown as the top three graphs on these figures. The "smooth" response spectra, based on scaling of a typical UBC type spectra is also shown for reference[4]. The square root of the sum of the squares (SRSS, essentially the peak motion derived from the x and y components) is also shown on the graphs. The lower

[4] The "smooth spectra" are based on a scaling a UBC response spectral shape by appropriate Ca and Cv values which were derived from enveloping the site-specific spectra.

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left figure shows the recommended response spectra and compares this spectra to the SRSS spectra and the response spectra recommended by Adan and Rollins. The lowermost center and right figures show the site-specific response at various damping ratios[5] and the recommended smooth response spectra for design derived based on the site specific-response.

The response spectra calculated for the 10 percent in 50 year events and the MCE event at the above damping ratios are shown on the attached Figures 4 and 5. We note that for time periods, T, of less than 1.0 second, our site-specific analysis exceeds the peak spectral acceleration values of the UBC 1997 and IBC 2000 (International Building Code) smooth spectra for both the 10 percent in 50 year events and MCE. As a comparison, the smooth spectra by Adan and Rollins (1993) for 0.35g and 0.70g, presented on Figure 9 of our 1996 report, envelop our calculated response spectra very nicely.

A summary of the recommended response spectra for selection and design of the base isolation system is shown on Figure 6, Recommended Response Spectra. In comparison to the 1996 report, the recommended response spectra extends the period of strong ground shaking out to a period of about 0.6 seconds for the 10 percent in 50 year event and 1.0 seconds for the MCE event. This finding is believed to be due to the relatively low shear wave velocities obtained in this investigation.

The recommended input ground motions are shown on Figure 7, Input Ground Motions. Due to the short duration of the normal faulting Helena earthquake, input ground motions for the Helena event should not be considered representative of an MCE event. These data have been provided electronically to the designers for their use. We recommend that when the final base isolation or other remedial system has been selected, a specific ground motion record be matched to the response spectra for final analysis and design of the rehabilitation.

6.1 REFERENCES

In addition to our previous investigations, the following references were used in this study

"Quaternary Tectonics of Utah with Emphasis on Earthquake Hazard Characterization Suzanne Hecker, Utah Geologic Survey Bulletin 127, 1993.

"Surface Rupture and Liquefaction Potential Special Studies Area Map," Salt Lake County, 1989.

"Seismic Hazard Maps for California, Nevada, and Western Arizona/Utah, Probabilistic Earthquake Ground Motions in the Western US," Art Frankel, et.al, U.S.G.S. Open File Report 97-130.

Only one component of the maximum ground motion is shown for clarity.

1997 NEHRP Recommended Provisions for Seismic Regulations for Rehabilitation of Existing Buildings (FEMA 273). National Earthquake Hazards Reduction Program.

"Shake: A computer program for earthquake response analysis of horizontally layered sites," Schnabel, Lysimer, and Seed, National Science Foundation, Report No. EERC 72-12, Dec 1972.

"Shake91: User's Manual," M. Idriss and J. Sun, University of California, Berkeley, Nov. 1992.

"Shakedit: pre & postprocessor for shake 91," Gustavo A. Ordonez.

"Damage Potential Index Mapping for Salt Lake Valley, Utah," S.M. Adan and K.M. Rollings, Utah Geologic Survey Misc Pub. 93-4, Jan 1993.

"Site Specific Strong Ground Motion Estimates for Salt Lake Valley, Utah," Wong, I. G. and Silva, W., 1992, Utah Geologic Survey, Miscellaneous Publications 93-9, October 1993.

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We appreciate being of service to you on this project. A more complete report summarizing the details of our analysis will be submitted shortly. If you have any questions, please contact the undersigned.

Respectfully submitted,

AGRA Earth & Environmental, Inc.

Joergen Pilz, State of Utah No. 168810
Professional Engineer

JP:ka

Encl.	Figure	1,	Site Plan
	Figure	2,	Soil Profile for Seismic Analysis
	Figure	3,	Initial Response Analysis Spectra
	Figure	4,	Response Spectra Summary for 10 Percent in 50 Year Event
	Figure	5,	Response Spectra Summary for MCE Event
	Figure	6,	Recommended Response Spectra
	Figure	7,	Input Ground Motions
	Appendix A,		Log of Boring B-2A
	Appendix B,		Results of the Shear Wave Velocity Measurements

Addressee (1)

cc: Mr. Parry Brown, PE
Reaveley Engineers and Associates, Inc.
1515 South and 1100 East
Salt Lake City, Utah 84105

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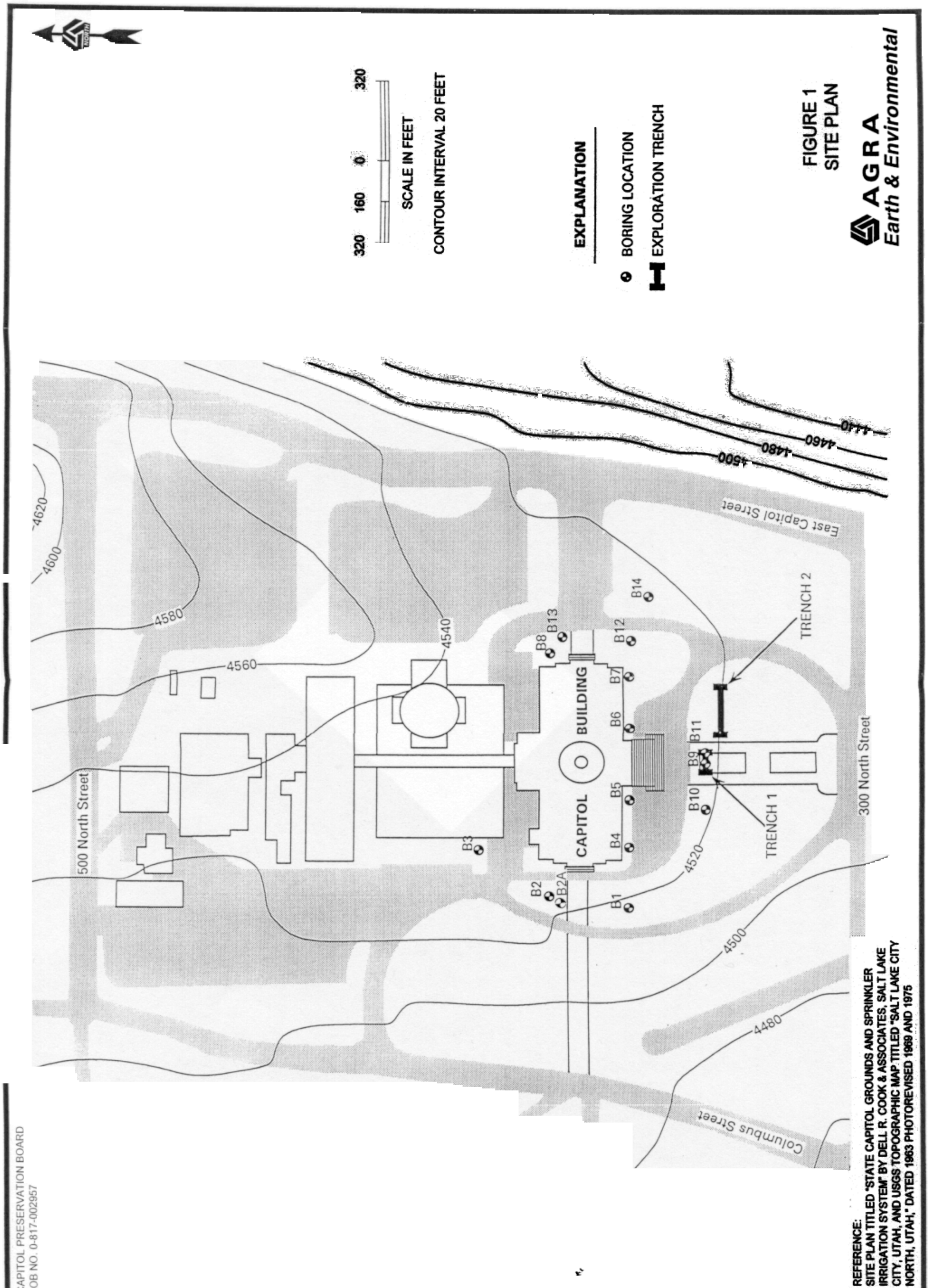
SCALE IN FEET
320 160 0 320
CONTOUR INTERVAL 20 FEET
EXPLANATION
BORING LOCATION
EXPLORATION TRENCH
FIGURE 1
SITE PLAN
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500 North Street
East Capitol Street
300 North Street
Columbus Street
CAPITOL BUILDING
TRENCH 1
TRENCH 2
B1
B2
B2A
B3
B4
B5
B6
B7
B8
B9
B10
B11
B12
B13
B14
4620
4600
4580
4560
4540
4520
4500
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4440
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REFERENCE:
SITE PLAN TITLED "STATE CAPITOL GROUNDS AND SPRINKLER IRRIGATION SYSTEM" BY DELL R. COOK & ASSOCIATES, SALT LAKE CITY, UTAH, AND USGS TOPOGRAPHIC MAP TITLED "SALT LAKE CITY NORTH, UTAH," DATED 1963 PHOTOREVISED 1969 AND 1975

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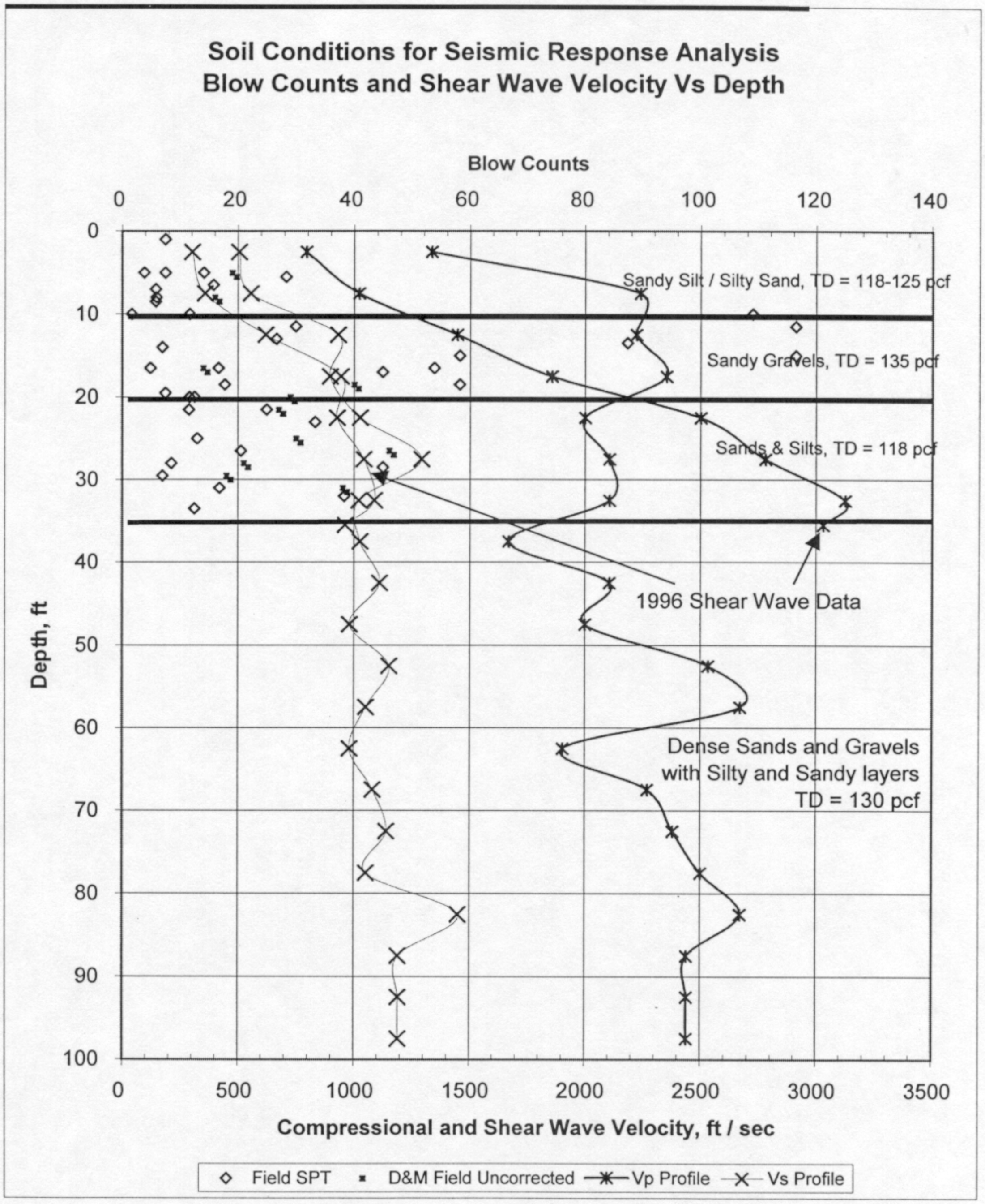

FIGURE 2
SOIL PROFILE
FOR SEISMIC ANALYSIS

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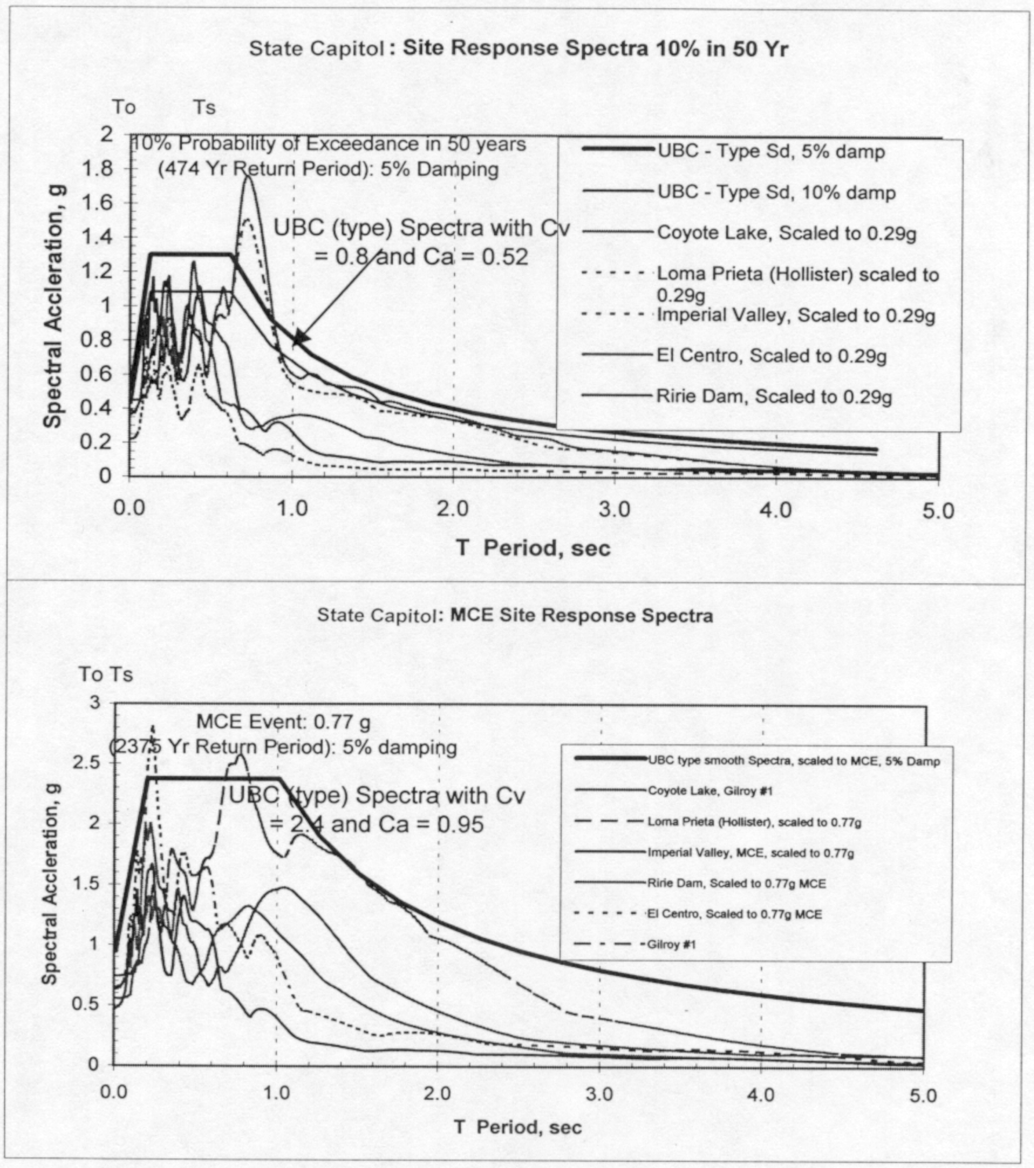

FIGURE 3
INITIAL RESPONSE
ANALYSIS SPECTRA

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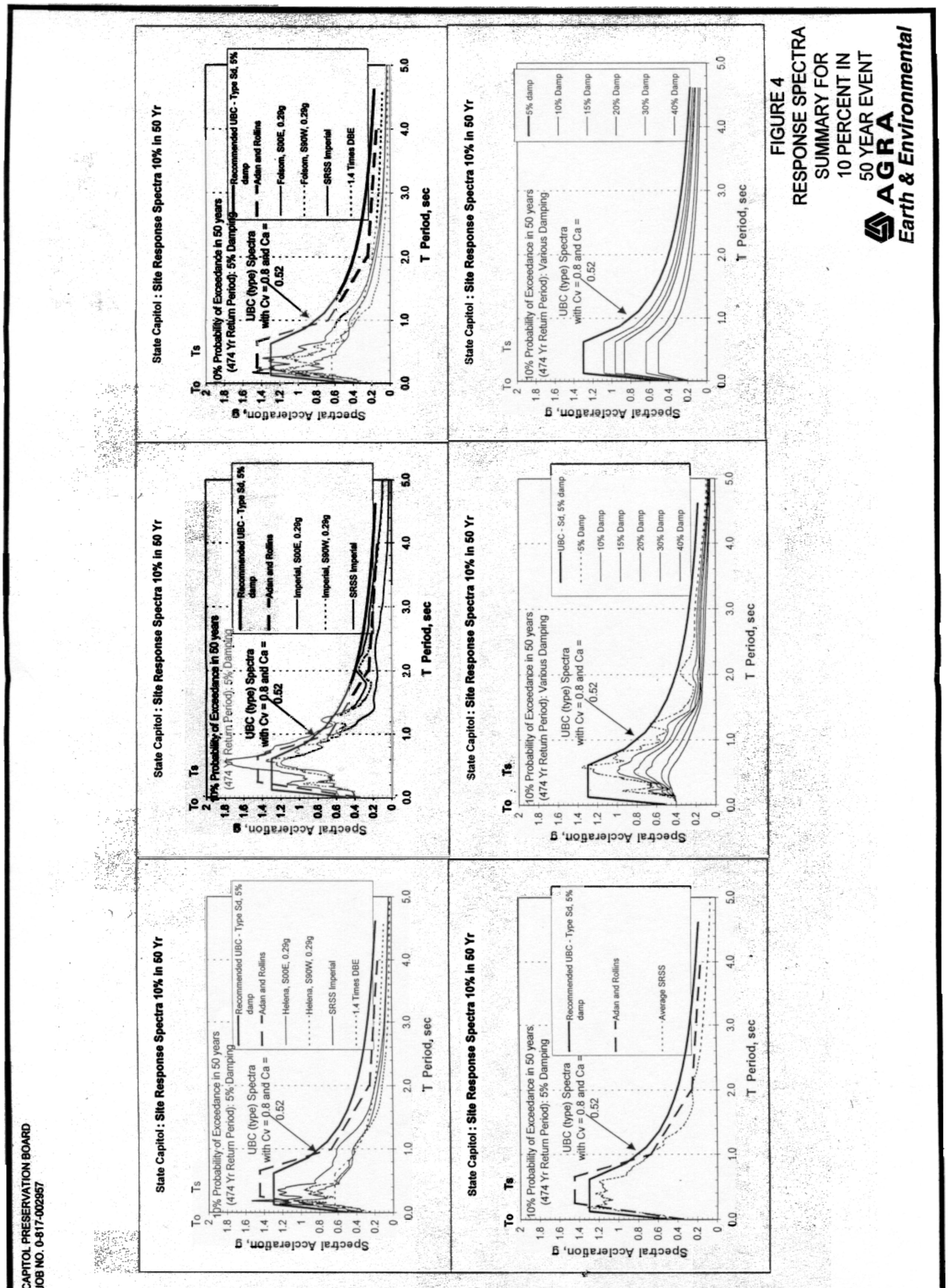
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State Capitol : Site Response Spectra 10% in 50 Yr
10% Probability of Exceedance in 50 years
(474 Yr Return Period): 5% Damping
UBC (type) Spectra with Cv = 0.8 and Ca = 0.52
Spectral Acceleration, g
T Period, sec
To
Ts
Recommended UBC - Type Sd, 5% damp
Adan and Rollins
Helena, S00E, 0.29g
Helena, S90W, 0.29g
SRSS Imperial
1.4 Times DBE
Imperial, S00E, 0.29g
Imperial, S90W, 0.29g
Folsom, S00E, 0.29g
Folsom, S90W, 0.29g
Average SRSS
(474 Yr Return Period): Various Damping
UBC - Sd, 5% damp
5% Damp
10% Damp
15% Damp
20% Damp
30% Damp
40% Damp
FIGURE 4
RESPONSE SPECTRA
SUMMARY FOR
10 PERCENT IN
50 YEAR EVENT
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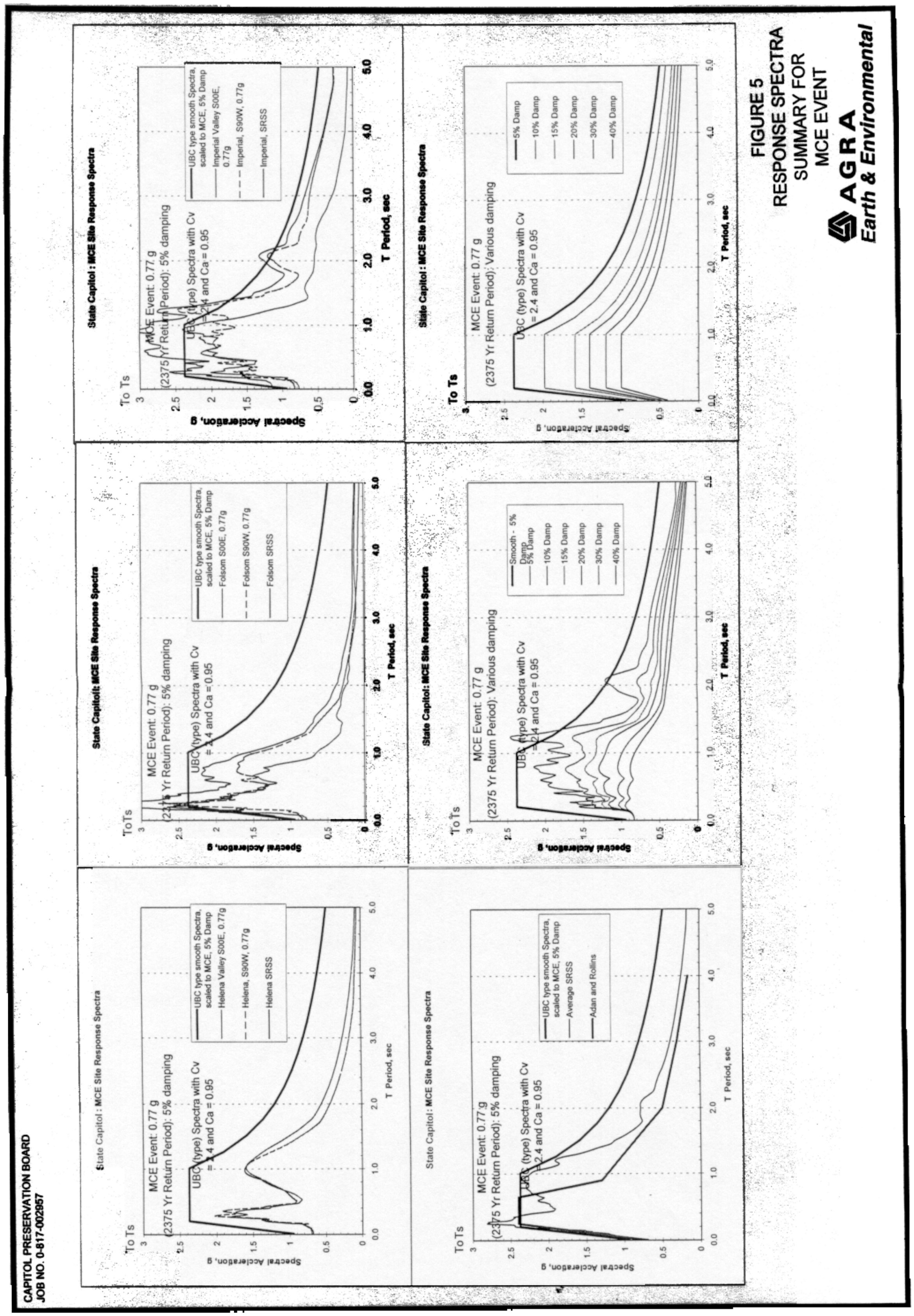

FIGURE 5
RESPONSE SPECTRA
SUMMARY FOR
MCE EVENT

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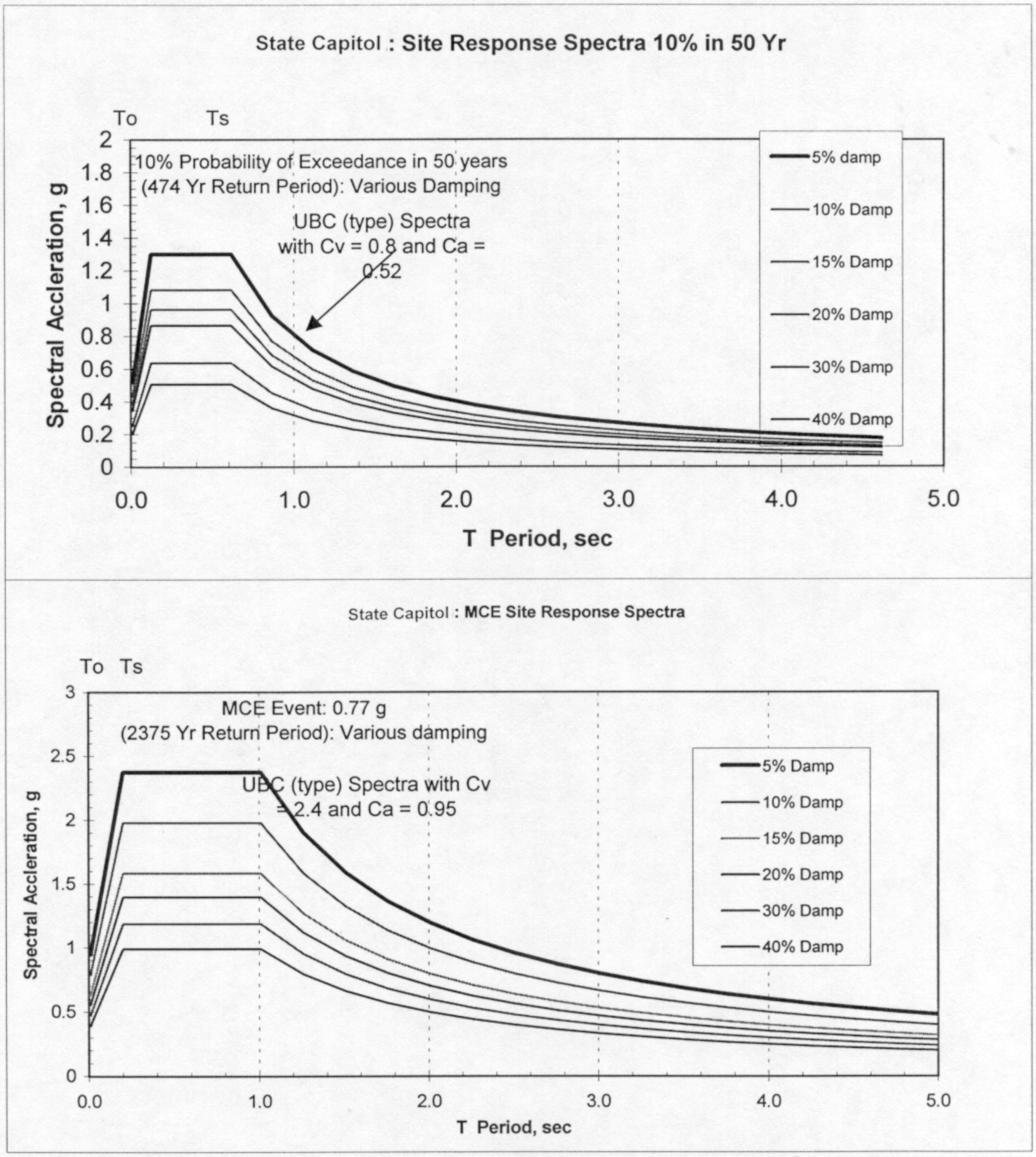

FIGURE 6
RECOMMENDED
RESPONSE SPECTRA

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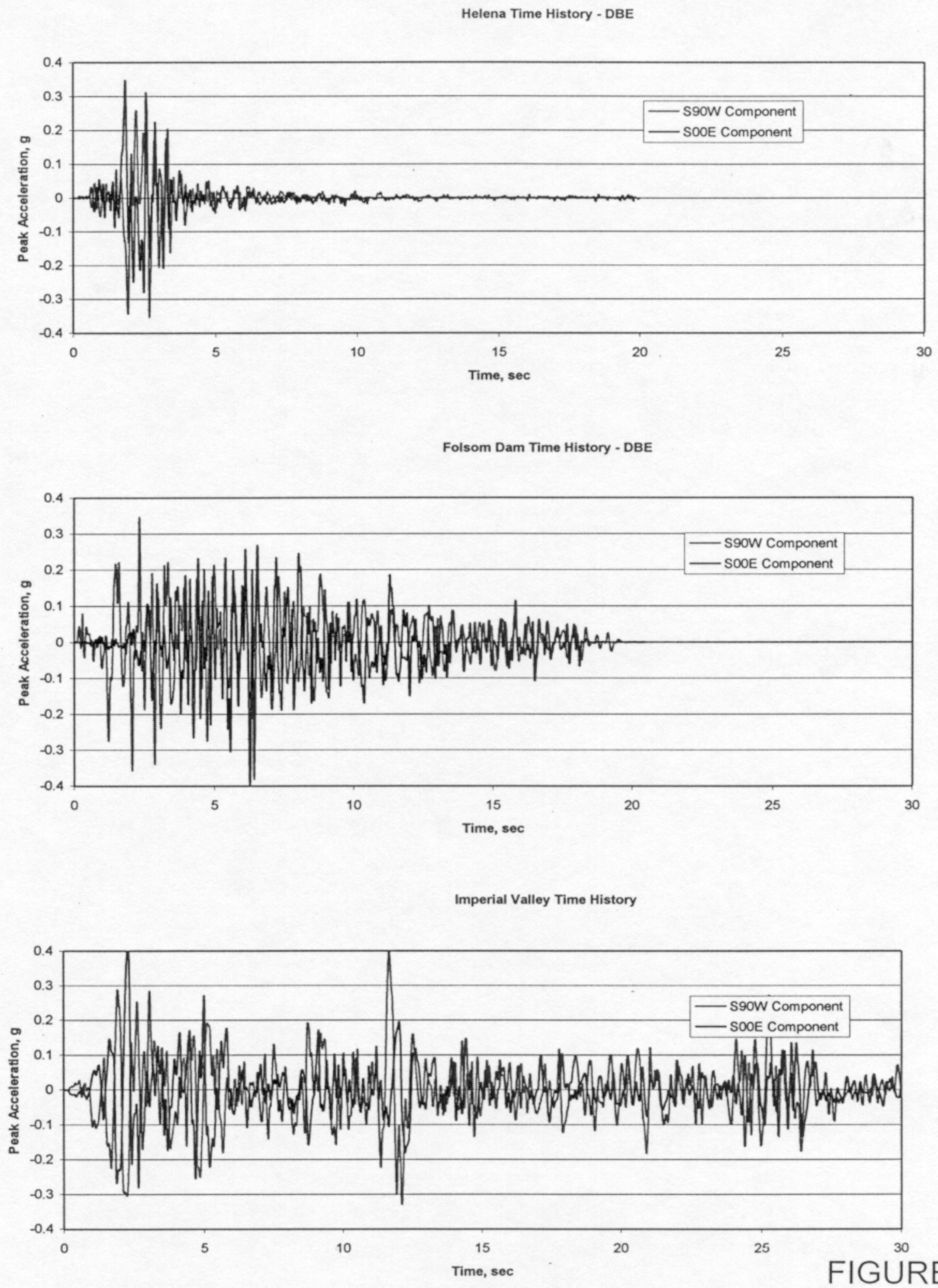

FIGURE 7
INPUT GROUND MOTIONS

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APPENDIX A

Log of Boring 2A

LOG OF TEST BORING NO. B-2A

PROJECT Utah State Capital Building
350 North Columbus Street, Salt Lake City, UT

JOB NO. 0-817-002957 DATE 05-15-00

RIG TYPE Rotary Percussion
BORING TYPE Rig P1000
SURFACE ELEV.
DATUM

Depth in Feet	Continuous Penetration Resistance	Graphical Log	Sample	Sample Type	Blows/foot 140 lb. 30" free-fall drop hammer	Dry Density lbs. per cubic foot	Moisture Content Percent of Dry Weight	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
0								ML/SM	moist to very moist "loose-soft"	**SILTY SAND/SANDY SILT**; fine to medium sand with some clay and with trace fine gravel; brown
5			X	A						
10			X	A						
15			X	A						
								SM/GM	slightly moist "dense"	**SILTY FINE TO MEDIUM SAND AND SILTY FINE AND COARSE GRAVEL** with occasional cobbles; brown
20			X	A						
25										

GROUNDWATER

DEPTH	HOUR	DATE
	*	

SAMPLE TYPE

A - Auger cuttings
S - 2" O.D. 1.38" I.D. tube sample.
U - 3" O.D. 2.42" I.D. tube sample.
T - 3" O.D. thin-walled Shelby tube.
D - 3 1/4" O.D. 2.42" I.D. tube sample.
C - California Split Spoon Sample

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PROJECT Utah State Capital Building
350 North Columbus Street, Salt Lake City, UT

JOB NO. 0-817-002957 DATE 05-15-00

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LOG OF TEST BORING NO. B-2A

RIG TYPE Rotary Percussion
BORING TYPE Rig P1000
SURFACE ELEV.
DATUM

Depth in Feet	Continuous Penetration Resistance	Graphical Log	Sample	Sample Type	Blows/foot 140 lb. 30" free-fall drop hammer	Dry Density lbs. per cubic foot	Moisture Content Percent of Dry Weight	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
25										
								GP	dry "dense"	**FINE TO MEDIUM SANDY FINE AND COARSE GRAVEL** with some cobbles; brown
30			X	A						
35										
40			X	A						
45										grades reddish-brown with trace silt
50										

GROUNDWATER

	DEPTH	HOUR	DATE
▽		*	
▼			

SAMPLE TYPE
A - Auger cuttings
S - 2" O.D. 1.38" I.D. tube sample.
U - 3" O.D. 2.42" I.D. tube sample.
T - 3" O.D. thin-walled Shelby tube.
D - 3 1/4" O.D. 2.42" I.D. tube sample.
C - California Split Spoon Sample

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ENGINEERING GLOBAL SOLUTIONS

PROJECT Utah State Capital Building
350 North Columbus Street, Salt Lake City, UT

JOB NO. 0-817-002957 **DATE** 05-15-00

LOG OF TEST BORING NO. B-2A

RIG TYPE Rotary Percussion
BORING TYPE Rig P1000
SURFACE ELEV.
DATUM

Depth in Feet	Continuous Penetration Resistance	Graphical Log	Sample	Sample Type	Blows/foot 140 lb. 30" free-fall drop hammer	Dry Density lbs. per cubic foot	Moisture Content Percent of Dry Weight	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
50			X	A						
55										
60			X	A						grades to fine and coarse gravel with some fine to medium sand and cobbles; reddish-brown
65										
70			X	A					"dense" to "very dense"	grades to fine to coarse sandy fine and coarse gravel with occasional cobbles; reddish-brown
75										

GROUNDWATER

	DEPTH	HOUR	DATE
▽		*	
▼			

SAMPLE TYPE

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AGRA
ENGINEERING GLOBAL SOLUTIONS

PROJECT Utah State Capital Building
350 North Columbus Street, Salt Lake City, UT

LOG OF TEST BORING NO. B-2A

JOB NO. 0-817-002957 DATE 05-15-00

RIG TYPE Rotary Percussion
BORING TYPE Rig P1000
SURFACE ELEV.
DATUM

Depth in Feet	Continuous Penetration Resistance	Graphical Log	Sample	Sample Type	Blows/foot 140 lb. 30" free-fall drop hammer	Dry Density lbs. per cubic foot	Moisture Content Percent of Dry Weight	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
75										
80				A						
				A				CL/ ML		**SILT TO SILTY CLAY LAYER**
85								GP		**FINE AND COARSE GRAVEL** with occasional cobbles and trace sand; brown
90				A						
				A						Practical refusal on cobbles
95										Stopped drilling at 93.0'. Stopped sampling at 93.0'. * Groundwater not encountered. The discussion in the text under the section titled, SUBSURFACE CONDITIONS, is necessary to a proper understanding of the nature of the subsurface materials.
100										

GROUNDWATER

	DEPTH	HOUR	DATE
▽		*	
▼			

SAMPLE TYPE

A - Auger cuttings
S - 2" O.D. 1.38" I.D. tube sample.
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APPENDIX B

Results of the Shear Wave Velocity Measurements

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RESULTS OF DOWNHOLE SEISMIC SURVEY, STATE CAPITOL BUILDING, SALT LAKE CITY, UTAH

Prepared for: AGRA Earth & Environmental
Salt Lake City, Utah

Prepared by: LGS Geophysics Inc.
Salt Lake City, Utah

June 2000

Introduction

Presented in this report are the results of a downhole, seismic survey conducted within a boring, located approximately 150 ft. west of the west entrance to the Utah State Capitol building, Salt Lake City, Utah. The purpose of the survey was to determine the shear and compressional wave portions of the seismic velocities of the subsoils at successive, five foot depth intervals within the boring. The ratios of the velocities and the shear wave portion of the velocities thus measured form the basis for determining the elastic moduli of the subsoils under dynamic, low strain (X 10-E5 to -E4 in./in.) and high loading rate conditions. These moduli, as determined by this type of survey, are a function of the gross strength characteristics of earth materials under these low strain and high loading rate conditions.

Field Investigations

Field investigations were conducted in June 2000. The boring had been cased with 4 in. ID, PVC casing and the annulus of the 10 inch diameter boring backfilled with a light bentonite/grout mix in preparation for the survey. The downhole measurements were conducted by using two orthogonal geophone units, spaced five feet apart, with each unit containing a vertical, a transverse and a radially oriented geophone. The field procedure consisted of placing the two units into the cased boring and recording the arrival of the various components of surface generated seismic waves as they arrived, successively, at the upper and lower units. This seismic energy for the shear wave measurements was generated by a horizontal impact on a weighted plank on the ground surface. This impact orientation generates a relatively large, horizontally polarized, shear wave component of the seismic wave form. The ground motions caused by this surface signal, on its successive arrival at the two geophone units in the boring, were then transmitted to the seismograph where it was subsequently amplified and recorded. The horizontal direction of the energy impact on the weighted plank was then reversed to confirm the onset of the shear wave arrival, thereby making use its polarization characteristic and facilitating its identification. The compressional seismic velocities were obtained by use of a vertically oriented hammer impact on the ground surface. The geophones were then lowered five ft. and the process repeated for each successive five foot depth increment to the bottom of the test hole.

Equipment:

A signal enhancement seismograph was used in the data collection. Filtering of the waveform was not used to avoid possible distortion of the seismic signals. A signal voltage sampling rate of 50,000 measurements per second was used in the analog to digital converter step to allow a high degree of accuracy (+ 0.1 milliseconds) in determining the arrival times of the seismic signals of interest. The frequency response of the vertical and the radial and transversely mounted, horizontal geophones within each of the geophone packages was 8 Hz.

Data Reduction, Comments

The use of two geophone packages, separated by a five ft. interval, enabled the measurement of interval times as well as the total travel time to the geophones from the source. Use of the interval times in the calculations avoids the possibility of potential measurement error due to any delay inherent in the timing system and essentially eliminates the affect of different travel time paths, of the seismic energy, as a source of error. Corrections were made in the depth increments in determining the seismic velocities to compensate for the 3 foot offset of the seismic source from the hole collar. An obstruction was encountered within the PVC casing at the approximate 91 foot depth and our survey was thus terminated at 90 feet instead of the original 100 ft. depth of the boring.

The shear modulus (G) was computed by the relationship given below, using the shear wave velocity (Vs) measured for each depth increment and the in situ density (d) of the material.

$$G = d(Vs)^2$$

(Vs = shear wave velocity in ft/sec)
(d=soil moist unit weight/gravity constant (32.2 ft./sec.^{2}))

A moist unit weight of 130 pcf was assumed for the soil column.

Youngs' modulus was then determined for each depth increment, using the shear modulus and Poissons' ratio for the same increment, by the following relationship:

$$E = 2G(1+p)$$

Poissons' ratio is calculated by:

$$(Vp/Vs)^2 - 2 \;/\; 2(Vp/Vs)^2 - 2$$

(Vp = compressional wave velocity in ft/sec)

<u>Results</u>

The results of the calculations together with the seismic velocities measured are presented on Table I.

We have appreciated providing this service to you. Please contact us if there are any questions on the above or if we may be of further service to you.

LGS Geophysics Inc.

Lamont Sorenson
Principal

TABLE I

RESULTS OF DOWNHOLE SEISMIC SURVEY

UTAH STATE CAPITOL BUILDING

DEPTH (ft.)	Vp (ft./sec.)	Vs (ft./sec.)	p	G (lb./ft.^{2})	E (lb./ft.^{2})
0 - 5	1333	505	.42	1.03 X 10E6	2.92 X 10E6
5 - 10	2240	555	.47	1.24 "	3.66 "
10 - 15	2222	930	.39	3.49 "	9.71 "
15 - 20	2353	895	.42	3.23 "	9.18 "
20 - 25	2000	1025	.32	4.24 "	11.19 "
25 - 30	2105	1290	.26	5.72 "	14.41 "
30 - 35	2105	1020	.35	4.20 "	11.34 "
35 - 40	1670	1025	.20	4.24 "	10.18 "
40 - 45	2105	1110	.31	4.97 "	13.03 "
45 - 50	2000	980	.34	3.88 "	10.39 "
50 - 55	2532	1150	.37	5.34 "	14.63 "
55 - 60	2670	1050	.41	4.45 "	12.55 "
60 - 65	1904	980	.32	3.88 "	10.24 "
65 - 70	2270	1080	.35	4.71 "	12.71 "
70 - 75	2380	1140	.35	5.25 "	14.17 "
75 - 80	2500	1052	.39	4.47 "	12.42 "
80 - 85	2670	1450	.29	8.49 "	21.90 "
85 - 90	2440	1190	.34	5.72 "	15.32 "

Vs = shear wave velocity (ft/sec)
Vp = compressional wave velocity (ft/sec)
G = shear modulus = $d(Vs)^2$
p = Poissons' ratio = $(Vp/Vs)^2 - 2 / 2(Vp/Vs)^2-2$
E = Young's modulus = 2G(1+p))
d = soil moist unit weight (pcf)/gravity constant(32.2 ft./sec.^{2}))